Section 22 Maine

Hydrology of Floods
Kennebec River Basin
Maine

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HYDROLOGY OF FLOODS
KENNEBEC RIVER
MAINE

BY
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DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

HYDROLOGY OF FLOODS
KENNEBEC RIVER
MAINE

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HYDROLOGY OF FLOODS
KENNEBEC RIVER
MAINE

1. PURPOSE

This report presents a review and analysis of the hydrology of floods on the Kennebec River in Maine. Included are sections on basin description, climatology, flood history, and analysis of recent floods. The purpose of the study was to review available hydrologic data and analyze the development and component contributions of floods on the river. The study was requested by the state of Maine to provide a foundation and direction for subsequent studies.

2. BASIN DESCRIPTION

a. General. The Kennebec River basin, located in west-central Maine, has a total watershed area of approximately 5,900 square miles, constituting almost one-fifth the total area of the State of Maine. The Androscoggin River basin lies to the west, the Penobscot River basin to the north and east, and a section of the Maine coastal area to the south. The northwesterly limit of the basin forms a part of the international boundary between the United States and Canada. The basin has a length in the north-south direction of about 150 miles and a width of about 70 miles. The upper two-thirds of the basin, generally above Waterville, is hilly, and mountainous being part of the Appalachian Mountain Range. The lower third of the basin, including the Sebasticook River and Cobbosseecontee Stream tributary areas, has a more gentle topography representative of the coastal area. A map of the Kennebec basin is shown on plate 1.

b. Kennebec River. The Kennebec River originates at the outlet of Moosehead Lake and flows southerly 145 miles to the head on Merrymeeting Bay at Abagadassett Point, about seven miles above Bath. From Merrymeeting Bay the Kennebec waters continue south, through the Maine coastal area, another 20 miles to the Atlantic Ocean at Hunniwell Point. The main river is tidal as far as Augusta, 25 miles above Abagadassett Point. Between its origin and mean tide at Augusta, the river falls about 1,026 feet in a distance of 120 miles, an average gradient of 8.5 feet per mile. One "S" curve in the river, between Madison and Skowhegan, form the only large digression in the river's southward course.

c. Tributaries. The principal headwater tributary is Moose River which drains 735 square miles of mountainous watershed area easterly to Moosehead Lake. The tributary area of the Moose River

d. Dams and Reservoirs. There are 17 hydroelectric dams in the Kennebec basin with ten located on the main stem Kennebec and having 95 percent of total generating capacity in the basin. Dams on the main stem harness approximately 50 percent of the total fall of the river.2/ All hydropower dams are run-of-river except Harris (Indian Pond) and Wyman which have storage capacity only for daily or weekly load fitting operations.

There is a total of about 1,300,000 acre-feet of reservoir storage in the Kennebec basin, used for hydropower regulation, with about 86 percent of that storage located in the upper 46 percent of the watershed, upstream of Bingham, Maine. The other 14 percent is generally distributed between the Sebasticook, Messalonskee and Cobbosseecontee tributary watersheds in the lower part of the basin below Waterville. Available reservoir storage in the upper basin has a marked effect on upper basin floodflow contributions to the Kennebec River. Principal storage reservoirs in the basin above Bingham are listed in table II. There are 1,132,000 acre-feet of storage in the basin and 1,016,500 acre-feet, or 90 percent at the three lakes: Brassua, Moosehead and Flagstaff.

3. CLIMATOLOGY

The Kennebec basin has a cool semi humid climate characteristic of northern New England. The summers are cool and the winters severe, particularly in the mountainous regions in the upper watershed. Average annual temperature is about 42^{0} F. Average monthly temperatures vary from 65 to 70^{0} Fahrenheit in July to 10 to 20^{0} F in January and February. Coldest temperatures occur at the higher elevations on the north westerly side of the basin. Extremes in temperature range from 90 to below minus 30^{0} F.

Average annual precipitation over the basin is about 42 inches occurring quite uniformly throughout the year. The area experiences periods of moderate storm rainfall as a result of low pressure systems moving up the east coast and from frontal systems moving from west to east across the country. Periods of moderate storm rainfall are usually not more than 1 to 2 days in duration. Storm rainfall amounts of 2 to 4 inches are relatively common but events of 6 inches or more are rare. Due to its northerly location the basin has escaped the brunt of coastal hurricanes with their accompanying intense rainfall. Much of the precipitation during

2/ Federal Energy Regulatory Commission "Water Resources Appraisal for Hydroelectric Licensing, Kennebec River Basin" 1980.

TABLE II

AVAILABLE RESERVOIR STORAGE
KENNEBEC RIVER BASIN ABOVE BINGHAM, MAINE

Project	Drainage Area (sq. mi.)	Surface Area (acres)	Drawdown (feet)	Storage (ac-ft)	Percent
Brassua Lake	710	8,979	30	196,500	17
First Roach Pond	63	3,270	7	21,500	2
Moosehead Lake	1,268	74,000	7.5	544,000	48
Indian Pond (Harris)	1,355	3,747	5	19,000	2
Moxie Pond	80	1,747	8	14,700	2
Flagstaff Lake	520	17,950	35	276,000	24
Wyman Lake	2,595	3,145	20	60,300	5
				1,132,000	100

the winter months occurs as snow with average annual snowfall ranging from about 65 inches along the coast to about 120 inches in headwater areas. The average water equivalent of the snowpack in the spring generally ranges from 5 to 8 inches with over 12 inches common in the upper interior areas of the watershed. During the spring months, March through May, the melting snowpack, independently or in combination with rainfall, is a prime producer of floods in the Kennebec basin.

4. STREAMFLOW

a. Runoff. Average annual streamflow in the Kennebec River basin is about 1.6 cfs per square mile of watershed area. This is equivalent to about 22 inches of runoff or about 50 percent of average annual precipitation. About 50 percent of average annual runoff occurs during the spring months of March, April and May.

b. Streamflow Records. Earliest streamflow data for the Kennebec River dates back to the 1890's with some unofficial data back to the early 1800's. Early data was recorded by dam operators on the river, principally the Hollingsworth and Whitney Company on the river at Waterville, Maine. The U.S. Geological Survey began installing gaging stations in the basin in the early 1900's and have operated a system of gaging stations, at various sites and periods of time, continuously to date. USGS stations, pertinent to the analysis of Kennebec River floods, and their respective periods of record are listed in table III. It is unfortunate that some of the long term stations have been discontinued in recent years. Supplemental flow and reservoir storage data for recent floods was furnished by the Kennebec Water Power Company.

5. FLOOD HISTORY

There are historical references to floods on the Kennebec River dating back to as early as January 1770 but there is little information on the relative magnitude of floods prior to 1892. It was in 1892 that the Hollingsworth and Whitney Company began to maintain records of flows in the river at their dam in Waterville. Comparative peak flow data for nine flood events in the basin since 1892 are listed in table IV. There are some inconsistencies in peak flow estimates for historic floods and many of the flood events included ice jams. The formation and breakup of ice jams could affect resulting local peak discharges and, most particularly, flood levels. The floodflow history would indicate that the December 1901 event approximated the March 1936 flood at Waterville. However, it is known that flood levels on the lower main stem of the Kennebec were affected in 1936 by ice jams. The March 1936 event is the greatest known historic flood on the lower main stem

TABLE III

PERTINENT USGS GAGING STATIONS
KENNEBEC RIVER BASIN

Station	Drainage Area (sq. mi)	Period of Record	Maximum Flow (cfs)
Kennebec River			
at Moosehead	1,268	1919-1982	16,700 - 3 May 1974
at Forks	1,590	1901-Present	30,300 - 1 Jun 1984
at Bingham	2,715	1908-1909 1931-Present	65,200 - 1 Jun 1984
at Waterville	4,270	1892-1954	154,000 - 19 Mar 1936
at N. Sidney	5,403	1978-Present	113,000 - 1 Jun 1984
Dead River			
nr. Dead River	516	1939-1982	18,000 - 12 Sep 1954
at Forks	872	1910-1979	28,700 - 20 Mar 1936
Carrabassett River			
nr. North Anson	353	1902-1907	30,800 - 19 Mar 1936
Sandy River			
nr. Mercer	514	1928-1979	38,600 - 19 Mar 1936
Sebasticook River			
nr. Pittsfield	572	1928-Present	14,400 - 22 Mar 1936

TABLE IV

KENNEBEC RIVER
FLOOD HISTORY (1892 - DATE)

Flood	Peak Discharges					
	Kennebec at Forks (1) (D.A. = 1,590)	Kennebec at Bingham (1) (D.A. = 2,715)	Kennebec at Skowhegan (2) (D.A. = 3,894)	Kennebec at Waterville (3) (D.A. = 4,270)	Kennebec at North Sidney (D.A. = 5,478)	Carrabasett Tributary (1) (D.A. = 353)
Mar 1896	-	-	-	113,000 cfs	-	-
Dec 1901	22,400	-	-	157,000	-	-
Apr-May 1923	17,700	-	-	135,000	-	-
Mar 1936	15,200	58,000	133,000(4)	154,000	-	38,000
Mar 1953	8,000	28,400	-	112,000	-	30,400
Dec 1973	24,900	50,300	110,000 (123,000)(5)	145,000(6)	-	20,000
Apr 1979	77,200	41,000	101,000	-	111,000	22,400
Apr 1983	28,300	55,400	82,000	-	107,000	13,700
May-Jun 1984	31,500	65,200	76,000	-	113,000	13,000

(1) USGS Gaging Station.
(2) Daily flow data by Kennebec Water Power Company and Central Maine Power Company.
(3) Data by Hollingworth and Whitney Company.
(4) From Corps file notes.
(5) Newspaper account of peak.
(6) From Regional Planning Committee Flooding Report dated February 1978.

of the Kennebec River. Floods in the basin have occurred most frequently in the spring as a result of snowmelt alone or in combination with rainfall. However, two floods were experienced in December both as a result of mostly intense rainfall. Also the most recent flood event, in May-June 1984, occurred as a result of intense rainfall following the snowmelt season. Though there was a great flood on the river in December 1901, hydrologic data for the event is sketchy and questionable due to difficulties in developing reliable rating curves. The major flood of 1936 was really the first event with reasonably sufficient flow data for analysis. Though the 1936 event was a major flood, Moosehead Lake storage controlled the flood runoff from its 1,268 square miles of watershed and contributions from the lake to downstream flood peaks were negligible. Similarly, in the lesser March 1953 flood, Flagstaff Lake, completed in 1950, in combination with Moosehead Lake, provided a high degree of control over floodflow contributions from their combined watershed areas of 1,788 square miles. In studies by the Corps in 1953 it was generally concluded, based on the flood history at that time, that floods on the Kennebec were produced largely by runoff from watershed area below Flagstaff and Moosehead Lakes, with these two lakes effectively controlling, or at least desyncronizing, flows from their watersheds, which represented 30 percent of the total Kennebec River watershed. It was further concluded that the mountainous Carrabassett and Sandy River tributaries were major contributors to flood peaks on the main stem Kennebec River. Since the flood of December 1953, and the last Corps analysis, there was major flooding on the Kennebec in December 1973, April 1979, April 1983 and May-June 1984. Current studies involved an analysis of these four most recent Kennebec River flood events.

6. ANALYSIS OF RECENT FLOODS

a. Procedure. Available streamflow data from the U.S. Geological Survey plus data provided by the Kennebec Water Power Company was used for the flood analysis. Flood inflow hydrographs to the three principal storages: Brassua, Moosehead and Flagstaff Lakes, were computed using reported average daily outflows and daily changes in lake storage data in the continuity equation:

$$\text{Inflow} = \text{Outflow} + \Delta \text{ Storage}$$

The resulting hydrographs at the storages, shown on plates 2 through 5, are approximate since they are based on average daily outflow and reservoir stage data. Hydrographs at USGS gaging stations are based on hourly data. Component outflow hydrographs were progressively combined and routed downstream. The routed hydrographs were checked for timing with USGS gaging station flow

snowmelt with mid day high temperatures near 70° F. Moosehead Lake was initially full and Flagstaff filled during the event. Analysis indicated that peak outflows from the lakes were about 40 percent less then peak inflows and lake outflows contributed about 30 and 15 percent of the peak flows at Bingham and North Sidney, respectively. This flood was less then that of December 1973 with peak flows generally ranging from about 70 percent as great in the upper basin to 80 percent as great as the 1973 in the lower basin.

d. April 1983. In April 1983, the Kennebec basin experienced about 2 inches of precipitation on the 17th and 18th, followed a week later by over 3 inches on the 24th and 25th with day time temperature highs in the sixties on the 20th and seventies on the 24th. The result was two flood events on the Kennebec River. Moosehead Lake was initially filled and Flagstaff Lake filled during the events. Lake outflows represented about 30 percent of the first flood peak at Bingham and about 40 percent of the second peak, whereas at North Sidney the analysis indicated that the lake outflows represented about 20 percent of both peak flows. Peak outflows from the lakes were only in the order of about 13 percent less then estimated peak inflows. The peak discharge of 28,300 cfs at the Forks established a new high for the period of record dating back to 1901, exceeding the previous high of 1973 by about 15 percent. The peak flow of 55,400 cfs recorded at Bingham was only about 5 percent less then the great flood of March 1936. In the lower Kennebec basin the April 1983 flood, though a major event, was apparently somewhat less then both the December 1973 and April 1979 flood events.

e. May-June 1984. The May-June 1984 flood event was the result of an intense storm occurring near the end of the normal spring runoff and reservoir refill period. Nearly 6 inches of rain was experienced from the 29th of May through the 2nd of June with about 2.25-inches experienced on the 29th. With Moosehead and Flagtaff Lake storages initially filled, about 40 percent of the peak flow at Bingham, and 25 percent at North Sidney were attributable to outflow from the lakes. Peak flows of 30,300 cfs at the Forks and 65,200 cfs at Bingham established new record flows at both locations. Peak flows on the lower Kennebec were believed somewhat less then either the December 1973 event or the historic 1936 flood but comparable to the April 1979 and April 1983 events. Peak outflows from the lakes were believed to approximate peak inflows during this major storm event.

7. STAGE-DISCHARGE RELATIONSHIPS

Kennebec River stages are directly related to magnitude of river flow, accept when local stage-discharge relations are affected by ice jams. During major floods, river levels are generally 20

TABLE V

KENNEBEC RIVER
STAGE vs. DISCHARGE

River Stage (ft)	Discharge: North Sidney Gage (cfs)	Discharge: Bingham Gage (cfs)	
6.2	2,780	215	
7.0	5,300	1,775	
8.0	8,530	4,600	
9.0	12,000	8,700	
10.0	15,700	14,100	
11.0	19,700	20,750	
12.0	23,800	29,090	
13.0	28,300	38,100	
14.0	33,000	48,370	
15.0	37,900	60,090	
(15.6´	65,200)		1984 Flood
16.0	43,000		
17.0	49,000		
18.0	55,000		
19.0	62,000		
20.0	68,000		
21.0	75,000		
22.0	82,000		
23.0	89,000		
24.0	96,000		
25.0	103,000		
26.0	109,000		
27.0	115,000		
28.0	122,000		
29.0	129,000		
(35.0´	160,000)		Est. 1936 Flood

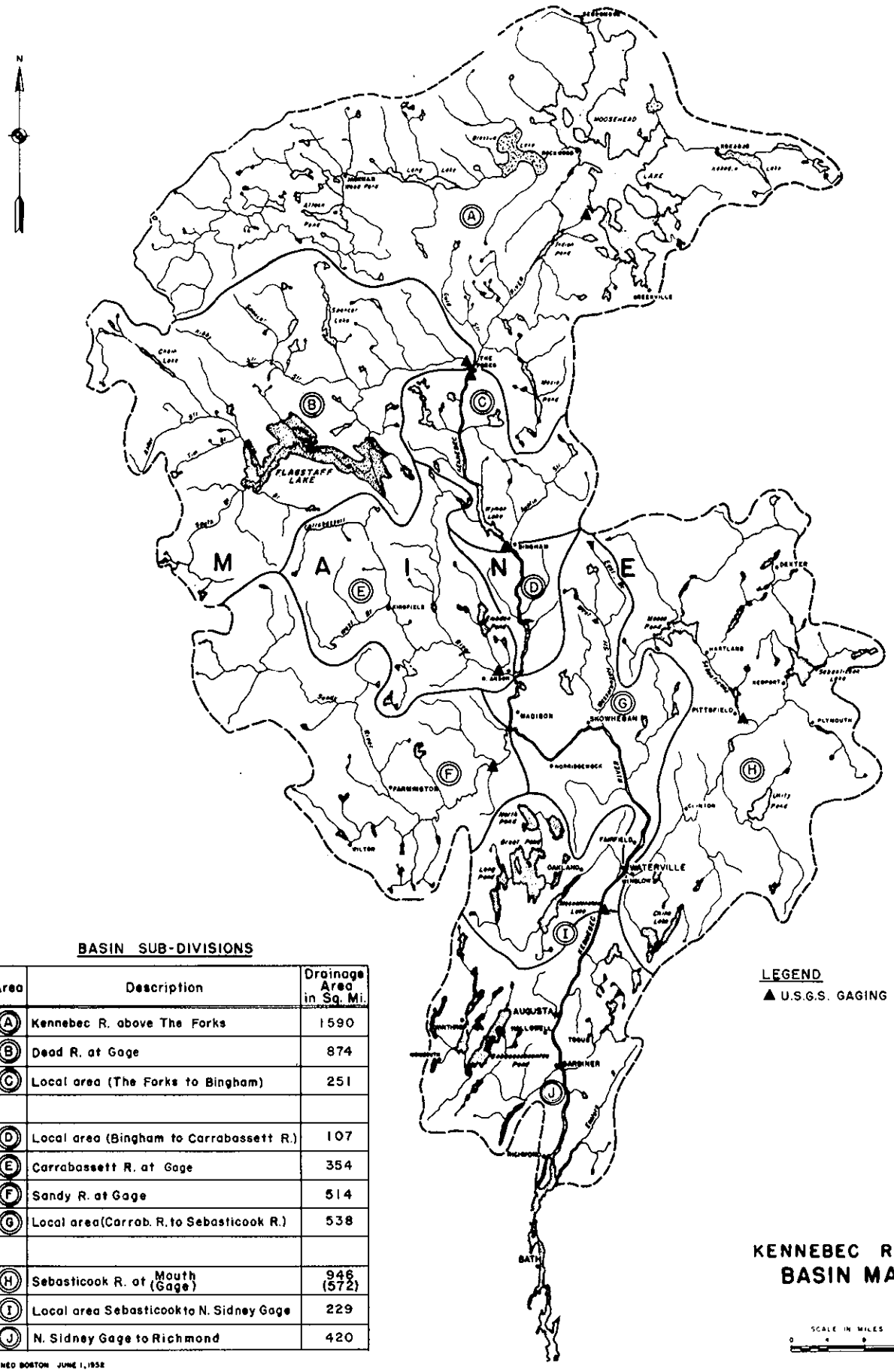
TABLE VI

KENNEBEC RIVER
COMPONENT CONTRIBUTIONS
TO FLOOD DISCHARGES

COMPONENT	Drainage Area (sq. mi)	Drainage Area (%)	PERCENT CONTRIBUTION TO PEAK FLOW 1953 Studies	1973 Flood	1979 Flood	1983 Flood	1984 Flood	1973-1984 Avg. Flood
AT BINGHAM GAGE								
Kennebec above the Forks	1,590	59	27	40	40	51	45	44
Dead River	874	32	35	32	35	26	40	33
Local	251	9	38	28	25	23	15	23
	2,715	100						
AT NORTH SIDNEY GAGE								
Kennebec above the Forks	1,590	29	7	14	12	22	24	18
Dead River	874	16	10	12	14	15	22	16
Local to Bingham	251	5	10	9	9	10	7	9
Carrabassett River	354	7	16	14	19	13	10	14
Sandy River	514	10	24	20	20	14	12	16
Sebasticook River	946	17	8	11	4	13	10	10
Local	874	16	25	20	22	13	15	17
	5,403	100						

The mountainous Sandy and Carrabassett River tributaries are high contributors to floodflows on the main stem Kennebec. While representing about 17 percent of the total basin watershed above Augusta they contribute 30 to 40 percent of the peak floodflow. Accordingly, the lower basin tributaries including the Sebasticook River are relatively low contributors due to their flatter topography and extensive lake storages.

The upper basin, including outflows from Flagstaff and Moosehead reservoirs, was a significant contributor to the four most recent flood events. The basin area above Bingham, representing 50 percent of the area above Augusta, contributed about 40 percent of the peak flow at Augusta, and the outflows from the two reservoirs, representing about 30 percent of the watershed area above Augusta, contributed about 20 percent of the peak flood discharge at Augusta. The upper basin reservoirs are operated generally for hydropower on the Kennebec River with some secondary seasonal operational restraints. A further phase of hydrologic studies would include an investigation of potential seasonal reservoir regulation "guide curves" to reduce the frequency and magnitude of reservoir outflow contributions to downstream floodflows, while not adversely affecting hydropower needs or other existing operational restraints. The studies should also establish the viability of temporarily using surcharge storage at the reservoirs in the interest of downstream flood control. It is emphasized, however, that such studies and any resulting "guide curves" could lull the public into a false sense of security. Guide curves, at best, would reduce somewhat the frequency and magnitude of floodflows. There still would remain the possibility of a major storm event occuring during the late spring normal full reservoir season. Also, if complete control at the two reservoirs were possible, which it is not, there would still remain a major flood potential from downstream watershed runoff. As previously stated, outflows from the reservoirs during the recent floods represented an estimated average 20 percent contribution to the peak flow at Augusta. This represents a 3 to 4 foot contribution to a river stage of 20 to 25 feet above normal.



BASIN SUB-DIVISIONS

Area	Description	Drainage Area in Sq. Mi.
(A)	Kennebec R. above The Forks	1590
(B)	Dead R. at Gage	874
(C)	Local area (The Forks to Bingham)	251
(D)	Local area (Bingham to Carrabassett R.)	107
(E)	Carrabassett R. at Gage	354
(F)	Sandy R. at Gage	514
(G)	Local area(Carrab. R. to Sebasticook R.)	538
(H)	Sebasticook R. at Mouth (Gage)	946 (572)
(I)	Local area Sebasticook to N. Sidney Gage	229
(J)	N. Sidney Gage to Richmond	420

LEGEND

▲ U.S.G.S. GAGING STATIONS

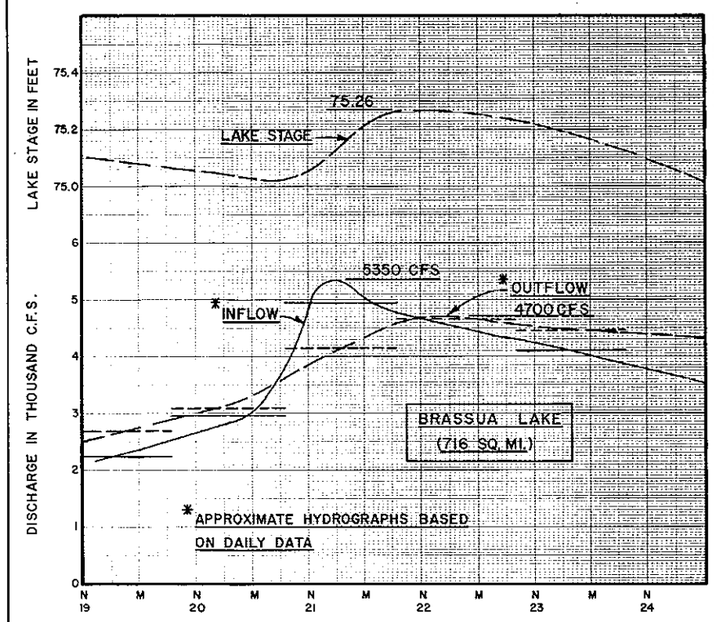
KENNEBEC RIVER BASIN MAP

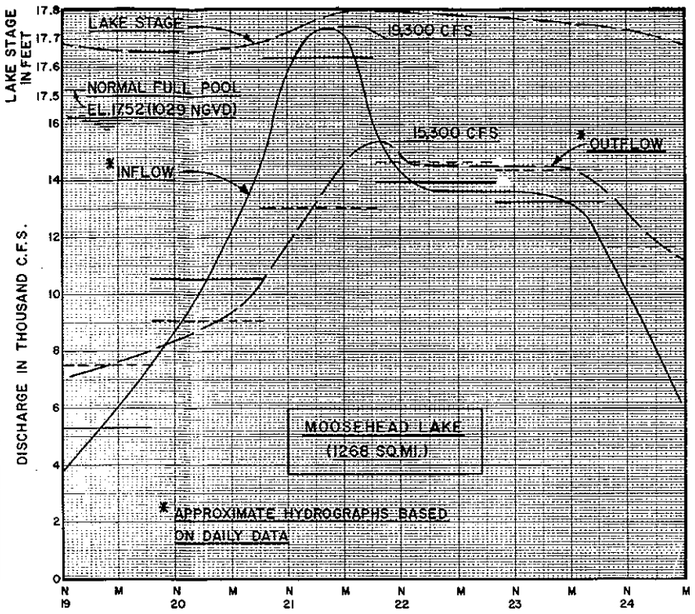
SCALE IN MILES

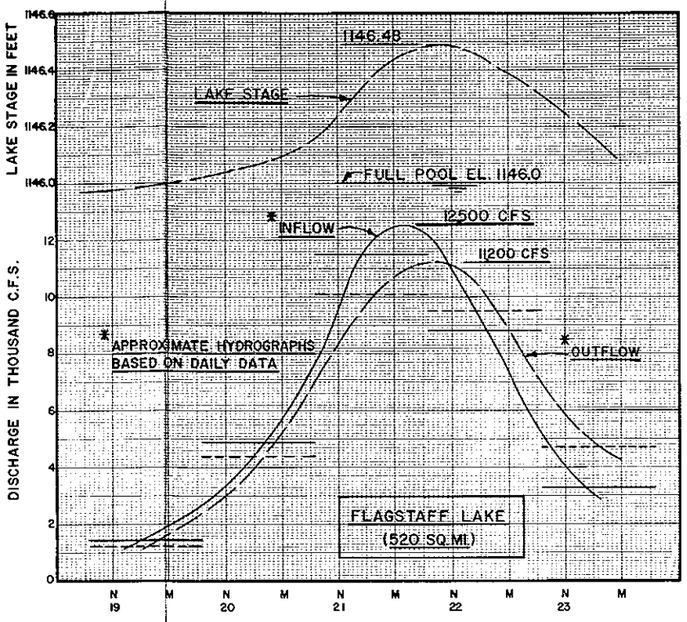
0 4 8 12

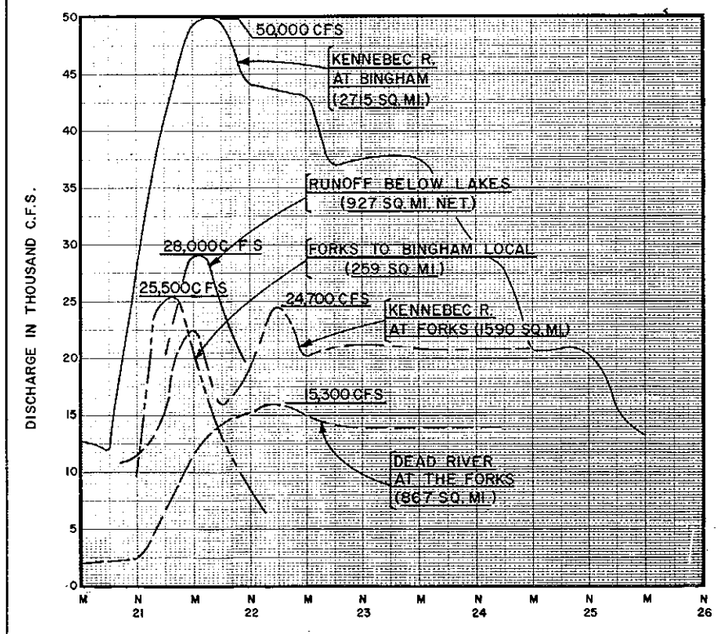
ARMY NED BOSTON JUNE 1, 1952

PLATE I

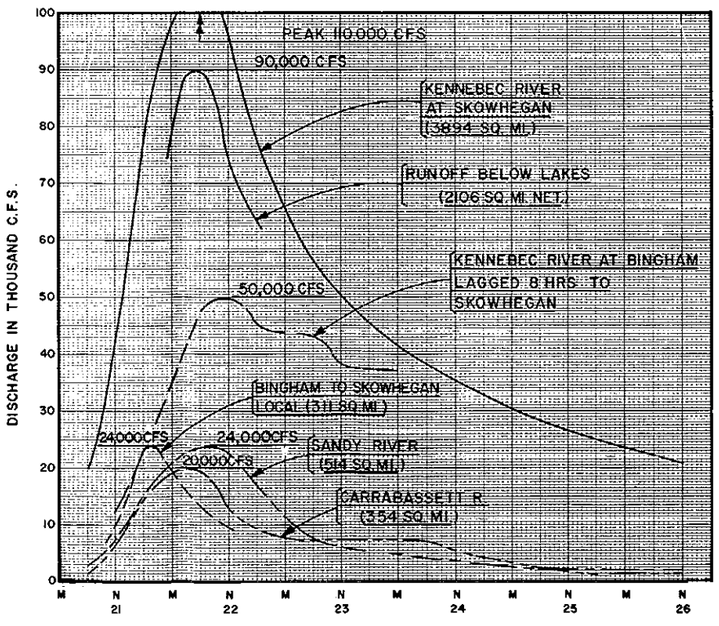








KENNEBEC R. AT BINGHAM



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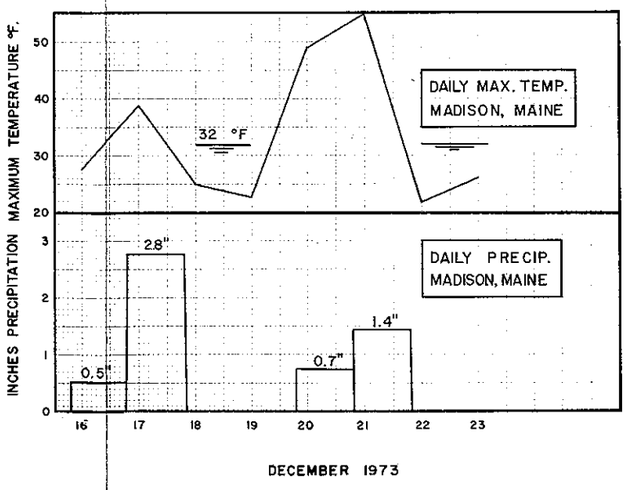


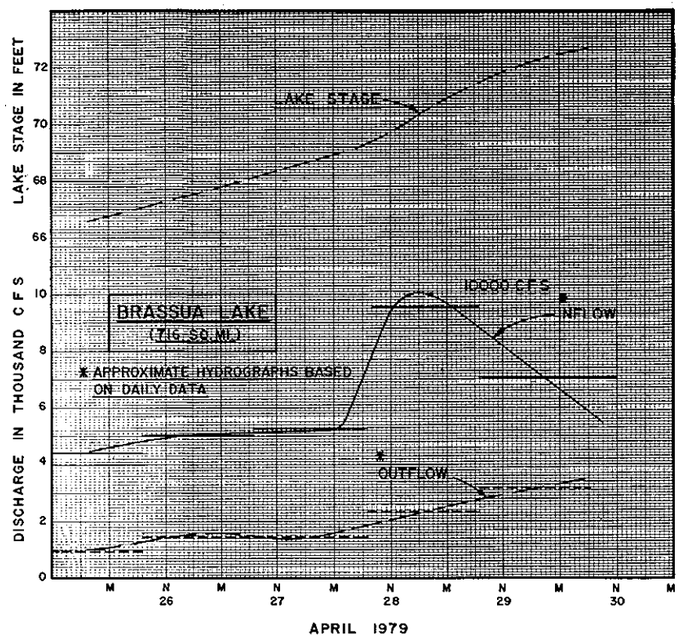
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

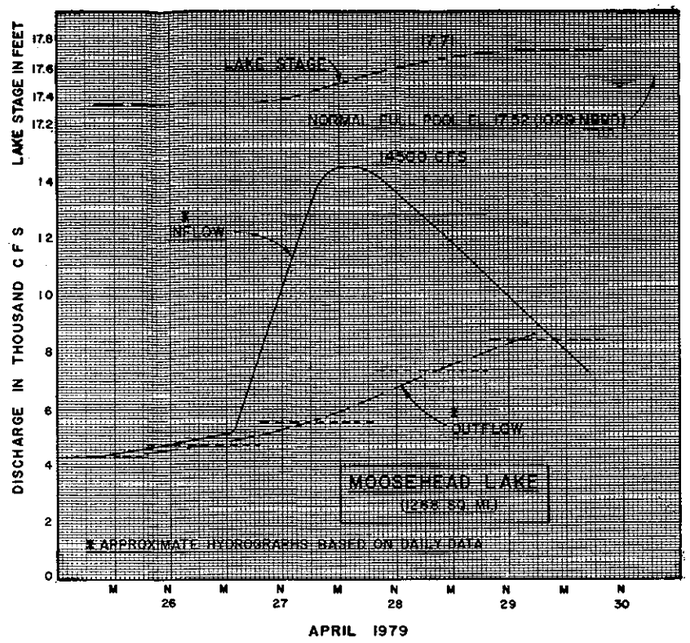
KENNEBEC RIVER BASIN

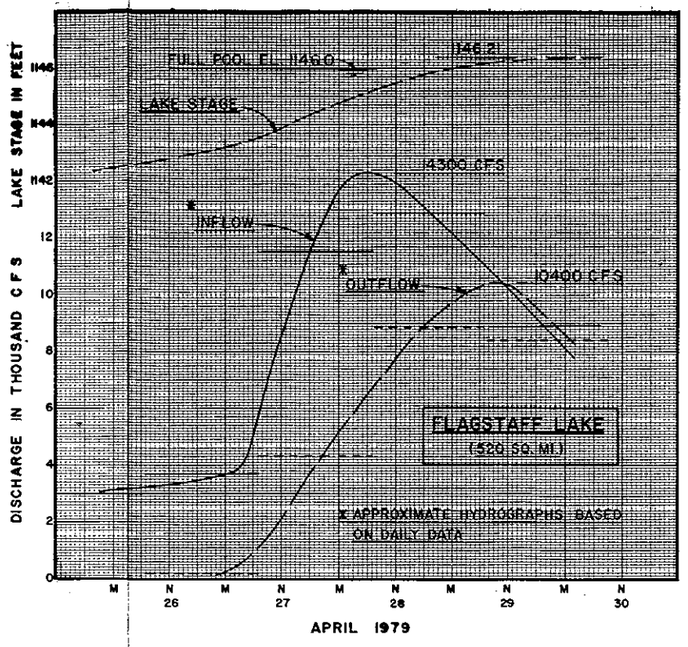
DECEMBER 1973 FLOOD ANALYSIS

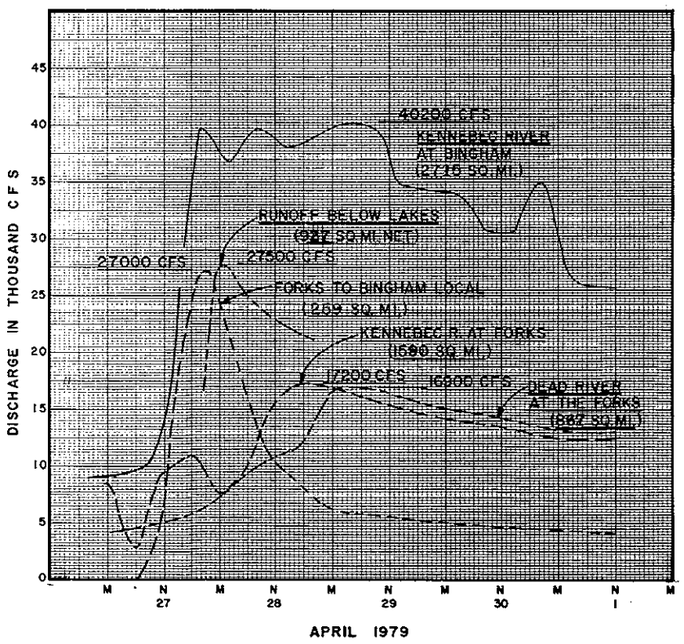
KENNEBEC RIVER — MAINE

PLATE 2

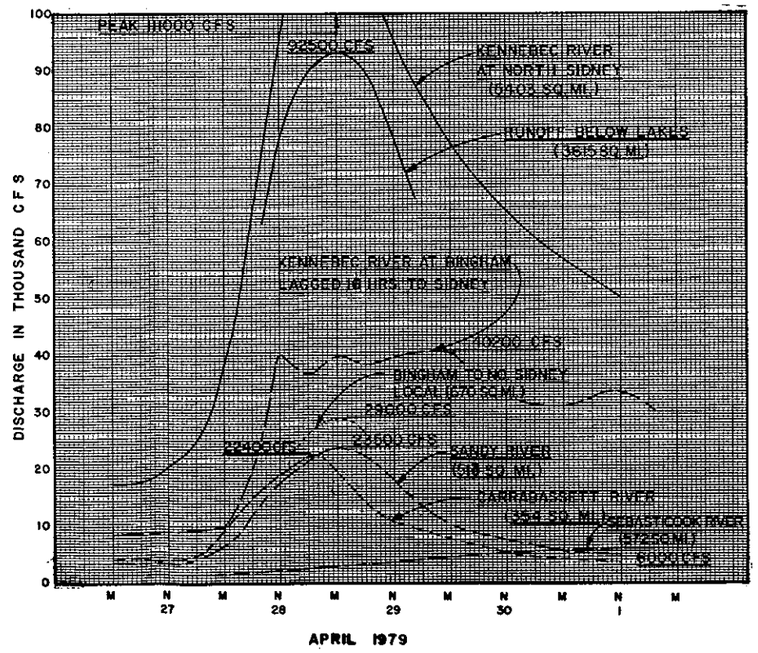




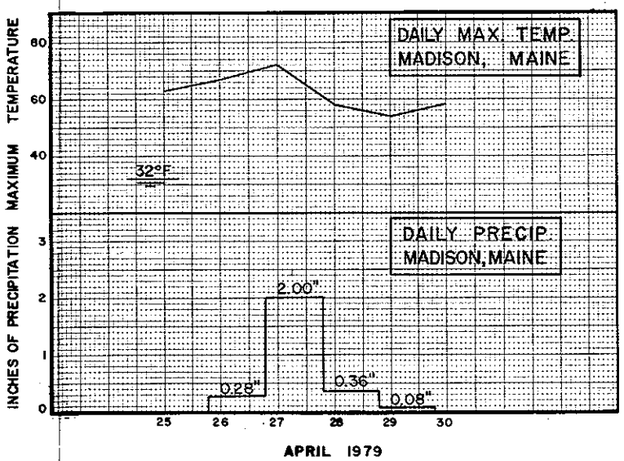




KENNEBEC R. AT BINGHAM



KENNEBEC R. AT NORTH SIDNEY



DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
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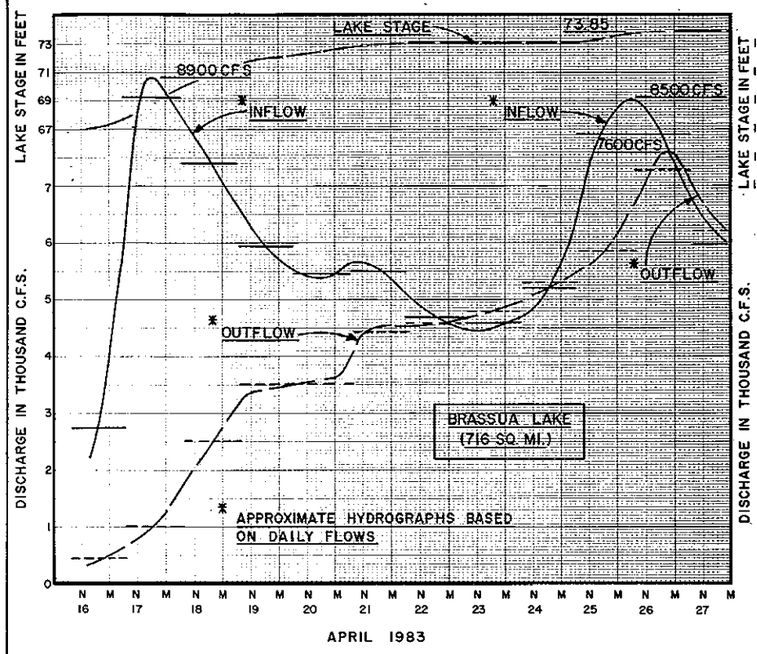
WALTHAM, MASS.

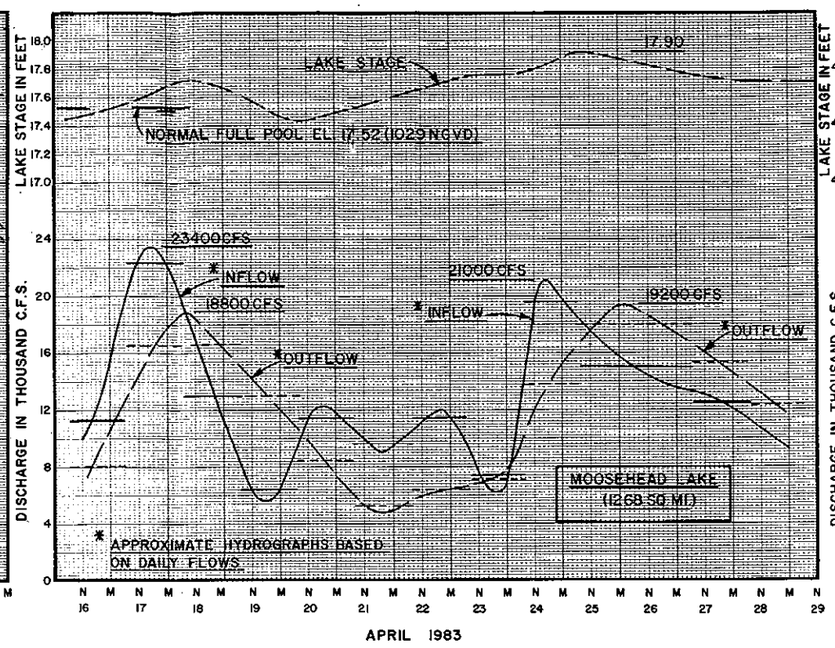
KENNEBEC RIVER BASIN

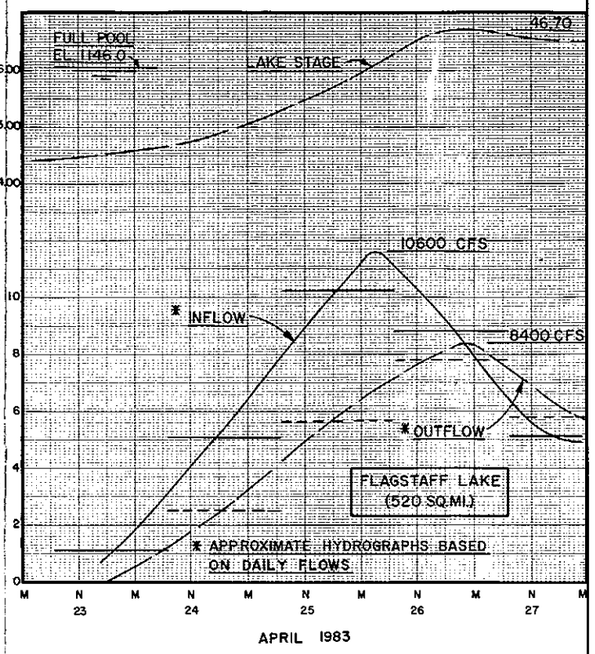
APRIL 1979 FLOOD ANALYSIS

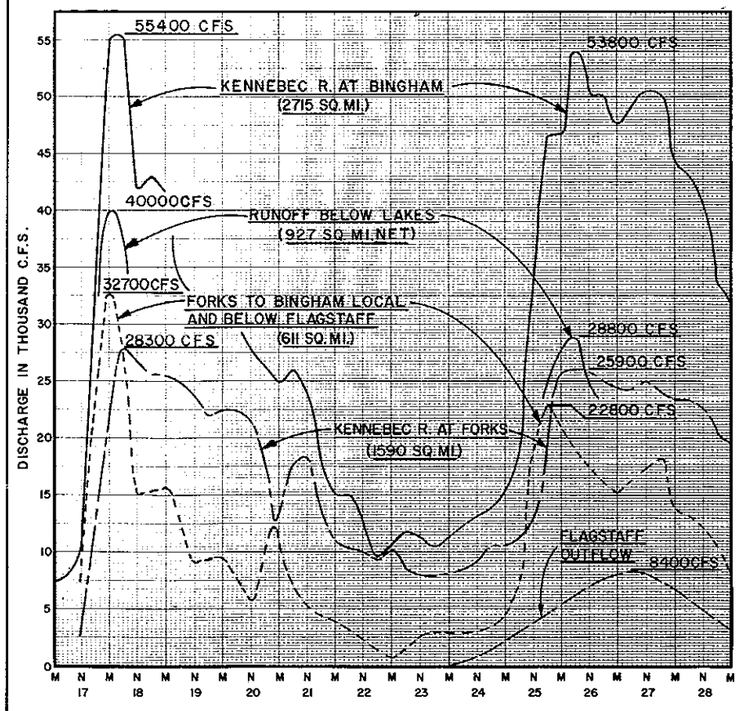
KENNEBEC RIVER — MAINE

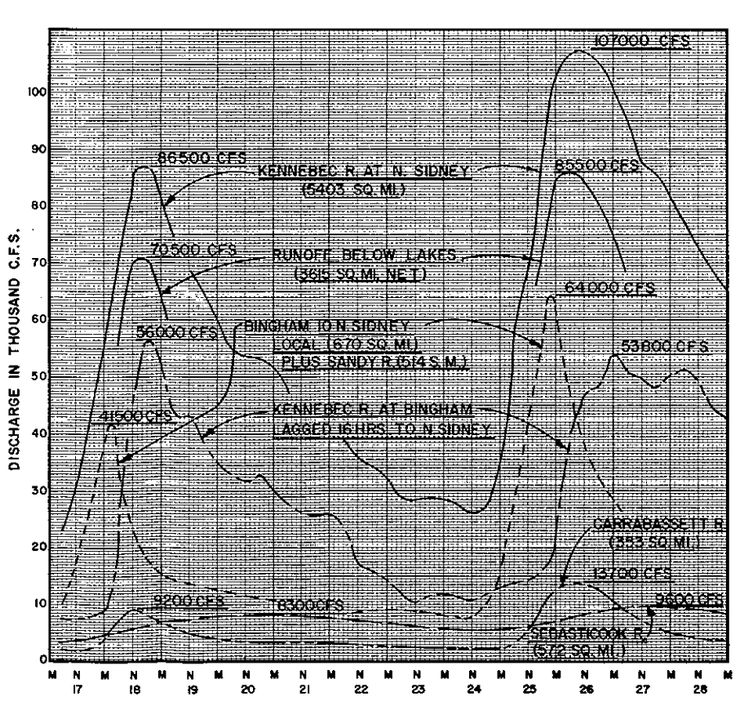
PLATE 3

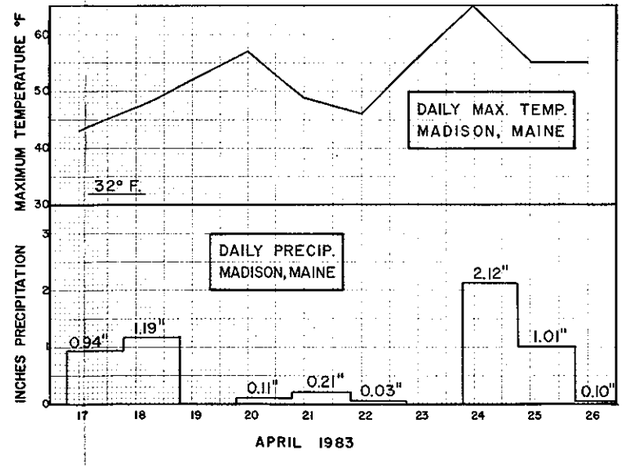












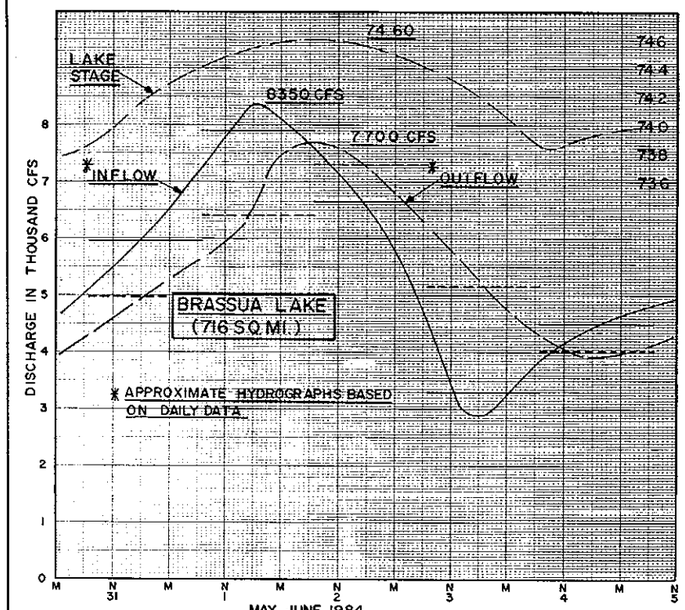
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

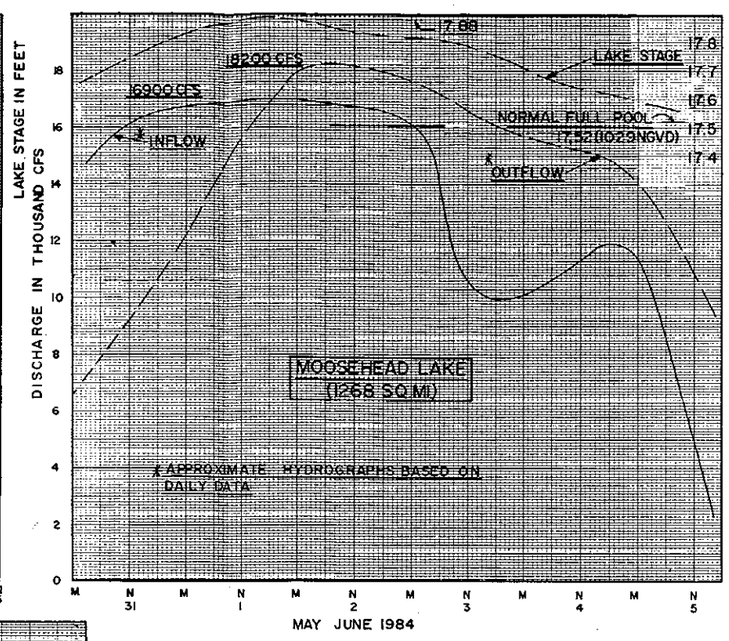
KENNEBEC RIVER BASIN

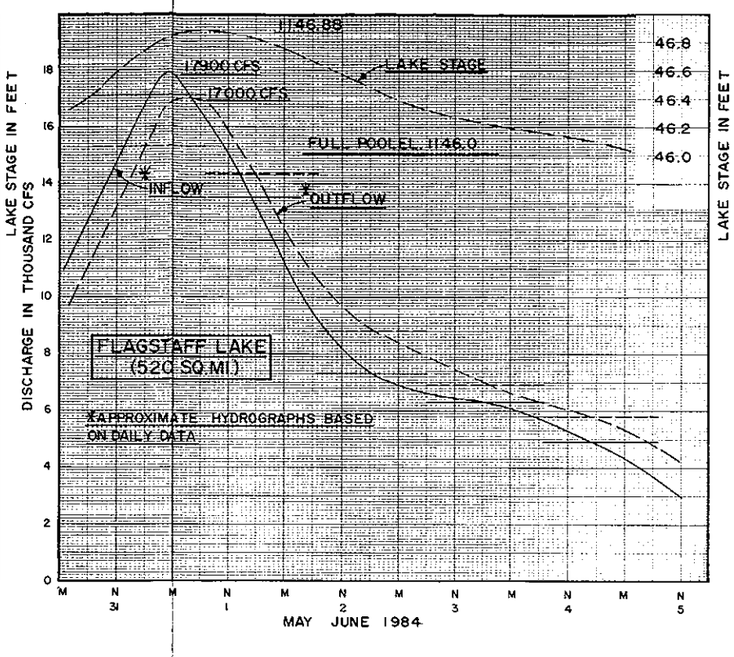
APRIL 1983 FLOOD ANALYSIS

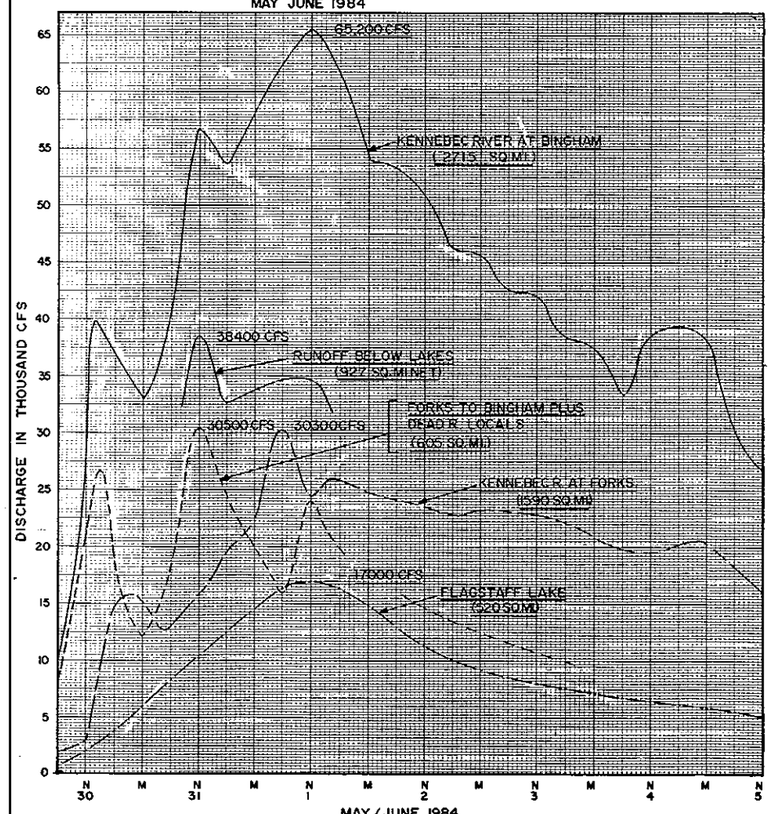
KENNEBEC RIVER — MAINE

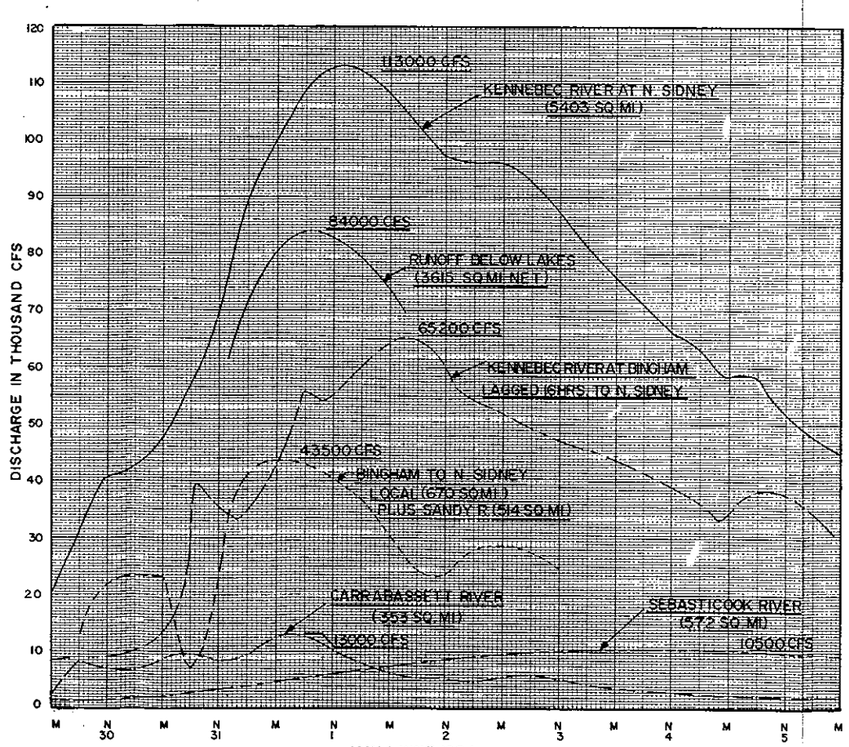
PLATE 4

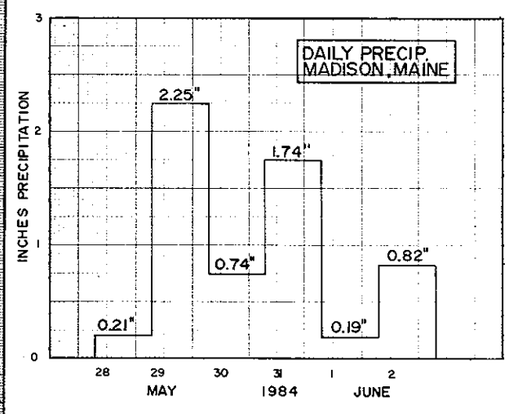












DEPARTMENT OF THE ARMY
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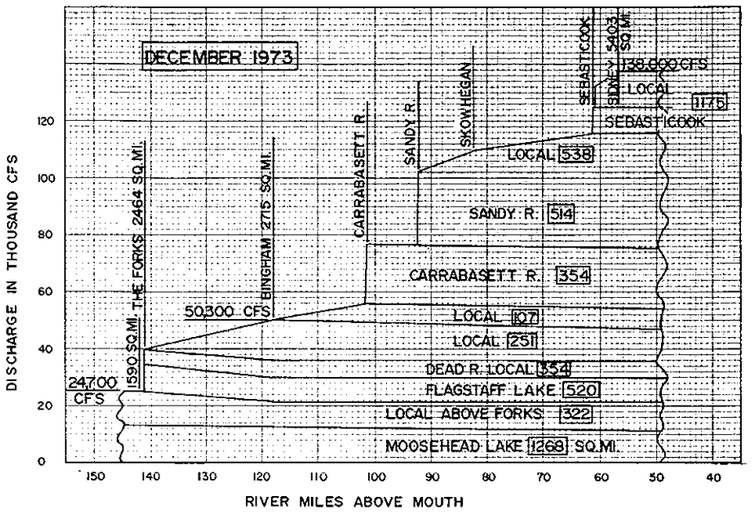
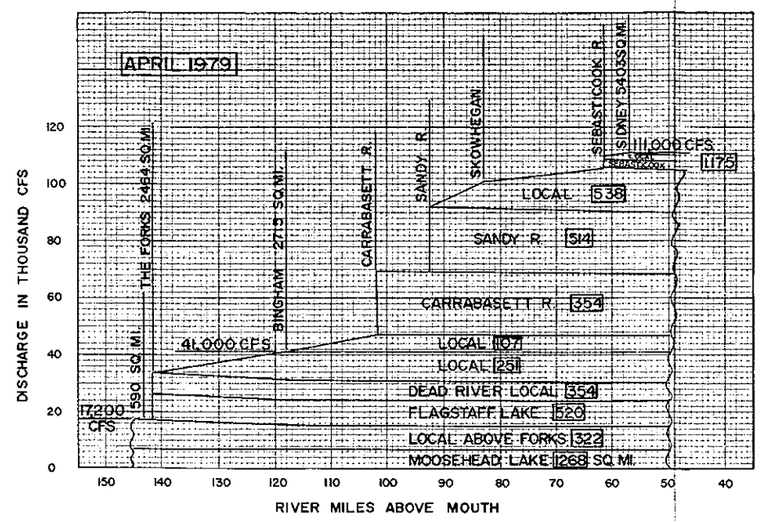
WALTHAM, MASS.

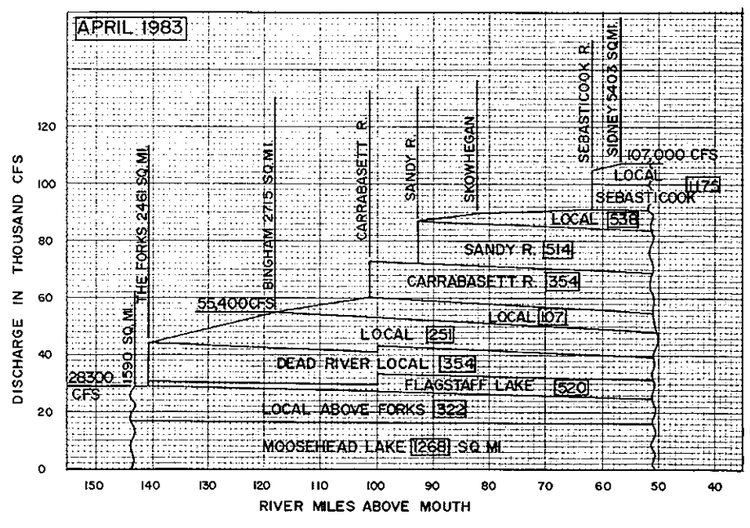
KENNEBEC RIVER BASIN
MAY/JUNE 1984 FLOOD
ANALYSIS

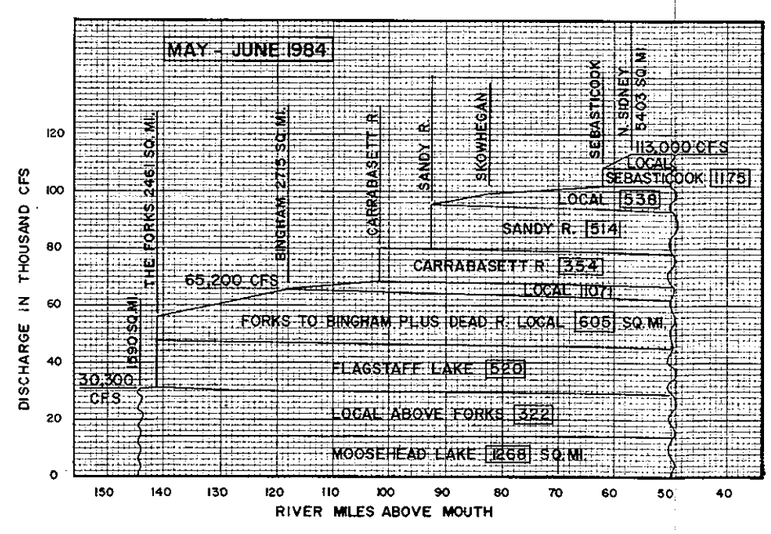
KENNEBEC RIVER — MAINE

PLATE 5









DEPARTMENT OF THE ARMY
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WALTHAM, MASS.

KENNEBEC RIVER BASIN
FLOOD DISCHARGE PROFILES AND COMPONENT CONTRIBUTIONS

KENNEBEC RIVER, MAINE

PLATE 6